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PRELIMINARY PLANNING for VEGETABLE DEHYDRATION

by

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Appendix

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Very large expansion of vegetable dehydration (the largest ever attempted) occurred during the first years of World War II. The construction of many plants was authorized, but only part of these were actually built and still fewer operated successfully. Most of the production came from a relatively small number of plants, and very few plants built during the War continued to operate in the post-war period.

The principal reasons for discontinuance of many successful plants were the cancellation of Government orders and absence of civilian markets to absorb the output from the war-expanded capacity. Many other plants, however, operated unsuccessfully, failed, or never got into production because of inadequate or improper planning. Studies conducted in this Laboratory during and since that period have brought together information on factors that contributed to many of those failures. Among the more important factors were the following:

1. Inadequate working capital.
2. Poor location with respect to suitable raw material.
3. Poor raw-material purchasing practices.
4. Careless or inexperienced management.
5. Inadequate, unsuitable, or poorly arranged plant facilities.
6. Costly fire losses.
7. Emergency shortages and delays in obtaining equipment, raw material, packaging supplies, and labor.
8. Poor location of plant with respect to sewage disposal.
9. Inadequate knowledge of proper processing techniques.
10. High cost of production--often the result of one or more of the above factors.

This publication is designed to introduce dehydration to a newcomer and to discuss some of the problems he must face in considering whether or not to attempt entry into that field. Accordingly, much of the information contained in this publication is well known to most experienced food processors. Very little of what follows is new or original. It does comprise, however, the first fairly complete introductory discussion of factors to be carefully considered before entry into the business of vegetable dehydration. It will also serve as background material for students and instructors of food technology.

In addition to sources of information suggested in the text, selected literature references classified by subject matter are given in Appendix B. The reader is strongly urged to peruse the literature listed as well as other publications dealing with dehydration.

Who Buys the Products?

The production of dehydrated vegetables has varied markedly over the past 35 years, mainly because of the effects of two World Wars. Production for representative years is shown in Table 1. The source of data is the "Statistical Review and Yearbook" issues of Western Canner and Packer.

Table 1. Estimated total production of dehydrated vegetables in the United States (millions of pounds)

1919	10.3	1941	13.2	1947	50.7
1925	1.3	1942	53.8	1948	179.5
1935	1.6	1943	125.5	1949	68.6
1937	1.5	1944	208.7	1950	60.0
1939	5.6	1945	130.3	1951	50.0
1940	5.4	1946	54.2		

The relatively large production in 1919 dropped to a peace-time demand of about 1.5 million pounds a year. Production increased in 1939 to over 5 million pounds and continued until it reached a record of over 200 million pounds in 1944. It again decreased after World War II. In 1948 a large quantity of potatoes was dehydrated. The raw material was purchased by the Government mainly for price support and the dehydrated product was sent overseas as foreign aid. Production of specific dehydrated vegetables is shown in Table 2 (also from issues "Statistical Review and Yearbook" of Western Canner and Packer.

Depending upon foreign and domestic conditions, the prospective dehydrator will have three markets to consider: (1) military agencies of the government, which take a large quantity of dehydrated vegetables in times of national emergencies; (2) other governmental agencies, which may purchase dehydrated foods or may lend or grant funds for such purpose; and (3) the civilian market, which takes a relatively constant quantity of dehydrated vegetables each year.

Military Market: The needs of the military agencies of the government for dehydrated vegetables have varied tremendously over the past years. Purchases in 1951 were only a small fraction of the quantity bought during the last year of World War II. Future procurements depend upon conditions yet to be determined. The potential scope of military procurements might be indicated from an analysis of World War II requirements.

After several years of experience in procurement under wartime conditions, the military agencies estimated their requirements for the 1945-46 fiscal year (in millions of pounds) as follows (as reported in the Proceedings of the Fourth Annual Meeting of the National Dehydrators Association, Chicago, Ill., Feb. 6, 1945):

Potatoes	134.0	Carrots	6.5
Sweetpotatoes	19.4	Beets	4.9
Onions	12.7	Rutabagas	0.6
Cabbage	8.7		

Table 2. Estimated total U.S. dehydrated vegetable packs, 1941 to 1950 inclusive
(millions of pounds)

Year	Beets	Cabbage	Carrots	Garlic	Onions	Peppers	Potatoes	Sweet-potatoes	Ruta-bagas	Tomatoes	All others	Total
1941	a/	a/	0.1	1.0	3.8	5.7	2.0	0.1	--	a/	0.5a/	13.2
1942	1.0	1.0	7.5	1.5	7.5	7.8	20.0	5.0	a/	a/	2.5a/	53.8
1943	3.4	3.7	20.4	2.0	9.4	4.4	71.0	7.2	1.0	1.0	2.0	125.5
1944	6.8	7.3	13.7	2.0	18.8	5.1	132.0	13.7	1.8	2.5	5.0	208.7
1945	5.0	5.0	7.0	2.0	10.0	7.3	75.0	15.0	a/	1.0	3.0a/	130.0
1946	a/	a/	2.0	2.0	10.0	17.2	20.0	2.0	--	a/	1.0a/	54.2
1947	a/	a/	a/	1.5	6.0	6.1	35.0	a/	--	a/	2.1a/	50.7
1948	a/	a/	a/	1.5	6.0	5.5	165.0	a/	--	a/	1.5a/	179.5
1949	a/	a/	a/	b/	8.0b/	8.6	50.0	a/	--	a/	2.0a/	68.6
1950	a/	a/	a/	b/	9.0b/	7.8	40.0	a/	--	a/	3.2a/	60.0

a/ Items combined under "All others".

b/ Garlic combined with onions.

When the War ended in 1945, production of dehydrated vegetables for the armed forces was reduced and these estimates were never realized. Armed Services' current requirements largely are confined to dehydrated potatoes, granules and dice, and to onions. The desirability and acceptability of the various dehydrated vegetables are continuously under study, and future military procurements will largely depend upon results of these studies.

The military planners believe that procurement of dehydrated vegetables should be limited to those preferred in the fresh form. That is, "If a soldier won't eat a vegetable when it is fresh or cooked fresh, he certainly won't eat it after it has been dehydrated." This naturally limits the number of vegetables that a prospective dehydrator must consider. It does, however, suggest some additional possibilities. Although tomatoes,(especially in the form of juice), green peas, snap beans, and sweet corn are highly regarded by the military, efforts by several research groups to devise satisfactory dehydration processes have not yet advanced to the point of commercial production. Successful dehydration and storage might open a large market in the Army, Navy, and Air Force and possibly even a civilian market for these products.

To obtain information on current program or to have one's name placed on the list for bid invitations, one should address communications to the Army Quartermaster Corps, Market Center System, 226 West Jackson Blvd., Chicago, Illinois.

Specifications for purchases intended for use by the armed forces are usually issued as Military Specifications by the U. S. Department of Defense. They take the place of the tentative specifications previously prepared by the Quartermaster Corps of the Army (generally known as "QMC Specs"). These specifications, however, may be modified by specific invitations for bids. Military specifications have been issued for the following dehydrated items: beets, cabbage, carrots, onions, potatoes, sweetpotatoes, rutabagas, and soup. Others are being prepared. Copies of QMC specifications can be obtained at the addresses given above.

Compared with civilian requirements, military requirements often differ in two important respects: (1) military specifications may provide for a very low moisture content, and (2) in wartime, packaging specifications may require tinned or lacquered cans of given size or substitute containers such as laminated moisture-proof bags, as well as specialized packing cases. No. 10 cans are the containers most often specified. Military specifications also require that certain dehydrated vegetables be packed in inert gas, such as nitrogen, and, in some cases, may specify the use of a desiccant.

Other Government Markets: During World War II, large quantities of dehydrated vegetables were purchased by the War Food Administration for shipment overseas to our allies. The demand is indicated by the following tabulation of estimates of requirements (in millions of pounds) for the fiscal year 1945-46 (as reported in the Proceedings of the Fourth Annual Meeting of the National Dehydrators Association, Chicago, Ill., Feb. 6, 1945):

Potatoes	30.5	Tomato flakes	4.0
Onion flakes and powder	10.2	Beets	2.8
Carrots	6.8	Garlic powder	2.0
Cabbage	5.3	Rutabagas	1.8

In the years following World War II, considerable quantities of potato flour were prepared and shipped abroad. The potatoes used were purchased by the government as a means of supporting the prices of fresh potatoes. While such support and use of potatoes or other vegetables may be carried on in the future, dehydrators can hardly rely solely on this market.

Non-military governmental purchases are likely to be covered by tentative specifications (issued by the U. S. Department of Agriculture) or by tentative federal specifications (issued by General Services Administration) for the following dehydrated products: beets, cabbage, carrots, celery, greens, onions, parsnips, potatoes, sweetpotatoes, rutabagas, and dry soup concentrate. If and when the government plans to purchase these products for either domestic use or foreign aid, information about such plans and the specifications that would be involved should be available from the U. S. Department of Agriculture, Washington 25, D. C.

Civilian Market: Important civilian uses for dehydrated vegetables are for condiments (onions, garlic, peppers), soup stock (in addition to those already mentioned, carrots, parsley, celery, potatoes), flour and granules (potatoes), and many specialty items. In 1951 the vegetable dehydration industry produced an estimated 50 million pounds of dry product, 60 percent of which was dehydrated potato products. The remaining 40 percent consisted of 9 million pounds of onions and garlic, 8 million pounds of peppers, and about 3 million pounds of other products. These figures include military and other governmental purchases as well as purchases by the civilian market. While less than half of the total production, or about 20 million pounds, went to the civilian market, this amount does represent a notable increase in civilian consumption over the approximately 5 million pounds produced in 1940.

From the standpoint of costs only, dehydrated foods can probably be sold at a lower price than other processed foods in most situations. This apparent price advantage evidently has not greatly affected demand for products other than vegetables for seasonings and soups.

General Product Requirements: Most military specifications for food state that the product being purchased must meet the requirements outlined by the Federal Food and Drug Administration. These regulations, also applicable to material produced for civilian use, cover labeling of the product as well as rules to assure wholesome and sanitary practices in the production and handling of food. The various States also enforce similar regulations.

Sometimes it is required that raw material for dehydration must equal a specific United States Standard (size limitation is sometimes excepted). The Standards referred to are the United States Standards for (specific commodity), and are currently distributed by the U. S. Department of Agriculture, Washington 25, D. C.

Federal Specifications (for example, Federal Specification, HHH-C-26 Cabbage: Fresh), often referred to in military specifications, can be obtained from the U.S. Superintendent of Documents, Washington 25, D. C.

How is Dehydration Accomplished?

Importance of Proper Dehydration Procedures and Where to Learn About Them: A thorough and continuing study of processes and equipment is imperative. Some information on technology is available in publications; however, the knowledge of many experienced operators and the results of much research in various research agencies have never been published.

Information about vegetable dehydration plants and operators might be obtained from the National Dehydrators Association, 520 North Michigan Avenue, Chicago 1, Illinois; from the National Food Brokers Association, Munsey Building, Washington, D.C.; and from the various growers' and processors' organizations in the respective States.

Prospective dehydrators should direct inquiries to the U. S. Department of Agriculture and to the State Agricultural Experiment Stations and Extension Services in the States in which they propose to locate their plants, particularly to departments of horticulture, agronomy, food technology, chemistry, chemical engineering, and agricultural economics.

Dehydration Procedures: The four basic steps in the dehydration of most vegetables are (1) preparing vegetables to desired form; (2) blanching or scalding and in some cases other preservative treatment such as sulfiting or starch coating; (3) drying; and (4) packaging. Some vegetables, for example onions and garlic, are not scalded.

Root vegetables are peeled, trimmed, and cut into desired shape such as dice, strips, shreds, or slices. Cabbage is cored and the outer leaves removed. Cabbage is usually cut into shreds as for krant. Blanching or scalding, partially through inactivation of enzymes, helps to stabilize flavor, color, and vitamins, and in general improves the palatability and nutritional quality of the product.

Practical commercial dehydration involves the passage of air, heated to proper temperatures and at the desired humidity, over or through the product. The vegetables may be spread on trays which are stacked on transfer cars. The cars are placed in cabinets or in tunnels in which heated air is blown across the trays. Conveyor-type driers are available in which the product is spread in a continuous layer on a moving belt. Heated air is usually blown through the mass of product on the belt.

Removal of the final and most difficult portion of the moisture may be accomplished in bins supplied with a slow through-circulation of air under carefully controlled conditions of temperature and humidity. Air-desiccation equipment for the final stages of drying and for packaging room may be necessary in areas having high relative humidity.

After the product has been dried to the desired moisture content, it is inspected, perhaps screened for removal of excessively small particles, and packaged. Metal cans are most commonly used. The armed forces usually prefer No. 10 cans, and the institutional and reprocessing civilian markets commonly use 5-gallon cans or large drums. In some cases, air in the container is replaced by an inert gas like nitrogen. The container, obviously, must be properly sealed to prevent loss of gas and to prevent entrance of moisture.

Typical flow diagrams for the usual basic steps involved in selected vegetable dehydration processes are presented in Appendix A. Procedures are outlined for handling potatoes, sweetpotatoes, onions, cabbage, and carrots in diced, sliced, or shredded form. Other vegetables and products often require different procedures.

Complete information on the process required should be obtained before a plant is even in the blue-print stage. This will help insure that the plant is designed to carry out the processing steps in the most effective and efficient manner possible. Even when the process promises at the outset to be entirely adequate, adjustments may be necessary because of changing or unforeseen conditions.

What Kind of Raw Material is Used?

Quality in vegetables is a very elusive property which easily disappears if the vegetables are not handled, processed, and packaged in a proper manner. Dehydration adds nothing to the original quality of vegetables; consequently the dehydrated product can be no better than the starting material.

Careful selection of raw material is essential. Certain varieties of a vegetable may make better dehydrated products than others. A variety that has proved best in one location, however, is not necessarily superior, or even acceptable, in another. A variety known to be generally suitable for dehydration must be grown in an area to which it is adaptable and under conditions which give optimum yields and quality.

In addition to varietal characteristics, one must consider such factors as maturity, solids content, and chemical composition. Immature vegetables are likely to be low in solids content, small, and otherwise unsuited for the production of a quality product at low cost. Overmature vegetables may be woody, fibrous, mushy, and in other ways lacking in quality.

A high-solids content is important in effecting low production costs through high yields of finished product, lower evaporation costs, and lower labor and other processing costs per pound of product. In some cases a better-quality product can be obtained from raw material that has a fairly high solids content.

As a rule, raw material is the largest single item of cost in vegetable dehydration. In some instances, it may amount to as much as 50 percent or more of the total cost of dry product. The procurement of proper-quality raw material, therefore, is of utmost importance to a successful and profitable operation. Factors other than price, important in judging raw material from a cost standpoint, include: (1) moisture content, as discussed above; (2) size and shape (smaller vegetables and irregularly shaped ones have higher peeling losses and lower yields and higher labor costs for peeling and trimming), and (3) condition (prime quality material has low cull-out and trimming losses).

An adequate supply of raw material is essential. The plant must be located at a place where a supply is assured. A plant processing 100 tons of potatoes a day over a 200-day season must have 20,000 tons of potatoes available each year. Some three thousand acres of land, yielding 250 bushels to the acre, are required to produce that quantity.

Large production of a vegetable in an area is not sufficient justification alone for the establishment of a plant in that area, since the market for fresh produce may be large enough to absorb the production. In appraising raw material supply, therefore, one must consider what effect the utilization of a large quantity of raw material for dehydration might have on an established economy--that is, what competition there will be with fresh-market demand or raw-product needs for other processing.

Growers often experience surpluses which they cannot sell in the usual markets. They then wish to find some other outlet. If dehydration is considered, the growers must determine whether the kinds of vegetables grown are suitable for dehydration, whether the varieties are proper, and whether a market exists for the products. In addition, the growers face the problem of deciding whether or not they wish to set aside a constant supply of vegetables each year for dehydration. Too often, some growers visualize dehydration as a means of utilizing intermittent surpluses, in which case they would do no dehydration in years of shortages or of stable fresh-market prices. Marketing of the dehydrated product, therefore, would be excessively difficult in view of the fact that a constant supply would not be made available for sale each year.

For an expanding military market or in times of national emergency, there may be an acute shortage of raw material, necessitating an expansion in acreage of certain vegetables. Additional acreage can sometimes be brought into production readily, because vegetables are annual crops. The suitability of any new areas to produce desirable quality material for dehydration must, of course, be proved in advance of plant construction.

The two usual methods of obtaining raw material are to contract in advance or to buy in the open market. For surety in both supply and price, the contract method is preferred. Many processing plants contract with growers for a certain acreage of vegetables before planting time. Prices can be set at time of contract or can be determined later in a prearranged manner. Open-market purchase is risky and in most cases undesirable. Often, however, a processor may buy additional quantities in the open market to fill out his processing schedule or to take advantage of a favorable price situation.

Where Should the Plant be Located?

Raw material supply is the prime factor affecting plant location. Consequently, any discussion of the suitability and availability of raw material is also a discussion of plant location. If an area has been selected from the raw-material standpoint, the location of the plant within the area then becomes mainly an economic matter.

First, how far from the source of raw material can one afford to go? With an over-all shrinkage ratio of 9 to 1 on potatoes, and higher on most other vegetables, a location as near to raw material supply as fe sible is indicated in order to effect the lowest possible total transportation cost of taking raw material to the plant and finished product to market. If, however, location near a single source of supply limits the plant to a very short operating season, another location may be advisable where additional raw material is available to extend the season. The reduced unit capital charge on the increased output might be sufficient to offset the higher transportation cost. Profit on a longer operating season must also be considered. Perishability of raw material is another factor to be weighed and may largely determine plant location irrespective of strictly economic factors in certain cases.

Many pertinent articles on plant location have appeared in various trade journals. A thorough review of several, some of which are listed in this publication, would be well worth the time of a prospective plant operator. Basic points covered in most of these articles include: (1) availability of an adequate supply of raw materials; (2) sufficient suitable labor for production and processing; (3) suitable fuel for providing steam, and for heating plant; (4) sufficient electric power for running equipment motors and dehydrator fans, and for lighting; (5) an ample supply of pure water; (6) adequate facilities for sewage disposal and prevention of nuisance odors; (7) sanitary condition of surroundings; (8) adequate transportation facilities; (9) experienced and financially responsible management; (10) suitability of existing facilities for expansion or conversion; (11) suitability of location with respect to military and civil defense.

A sound principle of plant location is to determine that location which, in consideration of all factors affecting delivered-to-customer cost of product, affords the greatest advantages possible by virtue of location. Factors should be reduced to a basis of cost of final product. Many of the more important items are so highly intangible, however, that their influence can be decided only by judgment. Thus selection of a plant location will be dependent partly on economic factors, perhaps reduced to a mathematical formula, but also partly on purely personal opinion.

What are the Labor Requirements?

Labor requirements in a vegetable dehydration plant range from the least skilled to highly specialized workers. No fixed number is required for a plant of a given capacity. Among the many factors that determine the number and skills of employees required are: (1) degree of mechanization of plant; (2) efficiency in layout of the plant and in use of equipment; (3) specific process utilized; (4) efficiency in use of employees; (5) type of raw material processed (size, shape, and condition); (6) skill of laborers available; and (7) scale of operation.

Labor cost is usually the second largest item of production cost, amounting to perhaps a quarter or more of the total production cost of many dehydrated vegetables. It is very important, therefore, that great care be exercised in the choice of process, plant, and raw material and in operation of the plant in such a manner as to make the most efficient use of labor.

Depending upon quality of raw material, type of process, etc., a plant handling one ton of raw potatoes an hour may require 20 to 30 employees for each. A five-ton-an-hour plant may require 75 to 100. A greater proportion of women workers will be required in the latter size of plant, because they are primarily assigned to trimming, sorting, and inspecting the product, functions that vary in magnitude almost directly with throughput. The relative savings in labor cost in the larger plant come mainly from operations other than those listed.

Multi-shift operation is common in the food processing industry during periods of peak harvest. During World War II, many dehydration plants operated 24 hours a day in three shifts. Continuous operation permits an orderly processing procedure with a maximum use of plant and equipment. While overhead and indirect costs are usually lower per pound of product when the plant operates more than one shift a day, unit direct labor costs will likely be higher. Night work usually commands premium pay; furthermore, the night crews are generally less efficient.

A short processing season causes higher labor turnover with the resulting inefficiencies inherent in such turnover. At the beginning of each season, new labor must be found and trained. Better-quality labor, and certainly more efficient labor, will likely be available if the dehydration plant operates the year round.

What Type of Management is Needed?

The wise selection of a location and the erection of an efficient plant are extremely important in the ultimate success of a dehydration venture and depend upon the wise execution of good initial planning. Management must be equally effective in operating the plant, particularly since new problems continue to appear.

Many attributes of good management are required. Among the more important ones are: knowledge and understanding of foods and food processing, ability to organize and supervise the labor crew, a good mechanical sense, understanding of record keeping and a ready interpretation of the results, and the ability to make most efficient use of production facilities and raw materials. Experience in dealing with and buying from fruit and vegetable growers is extremely valuable. Some successful dehydration plant managers during World War II had been shippers of fresh produce.

The administrative ability of the general manager is the key to successful plant construction and operation. Managing a dehydration plant of any practical size is a full-time job and will not permit the general manager to have other interests that keep him away from the plant. Because of the many problems that arise demanding careful consideration and immediate action, it is important that the manager not only have the "know-how" to solve the problems but also have ability, courage, and authority to make decisions quickly. An owner-manager combination is considered ideal for this position.

Three classifications of technical employees are required. The buyer of raw materials, or field agent, must have a broad knowledge of all phases of growing and handling the particular crops to be dehydrated, and he must command the respect and cooperation of the farmers.

The plant engineer must be an expert in the principles of dehydration; he should thoroughly understand and know what is available in equipment, supplies, etc.; he should be able to make most efficient use of the equipment; and he should be able to devise new techniques to meet ever-occurring new problems.

The quality control technologist is the expert in food technology, sanitation, and all other aspects of processing. Some knowledge of chemistry is essential.

The smaller dehydration plants may not be able to hire experts in each field. Any plant that does not have these abilities within its staff, however, will suffer severely from that lack.

The efficiency of a plant centers around the key supervisory and technical personnel Every effort should be made to keep a nucleus of important employees with which to start each season. If the plant cannot operate all year, perhaps the key employees can be kept busy in various jobs during the time the plant is shut down. Depending upon the abilities of the men involved, such jobs could include maintenance, improvement of plant layout, warehousing, shipping, box repair, and so forth.

A prospective dehydrator should seek the assistance of consulting firms competent in engineering, food technology, accounting, and legal problems in the construction and operation of a dehydration plant. Equipment manufacturers often offer engineering guidance; many suppliers of cans, chemicals, and other processing needs have technical staffs to assist processors in making most effective use of these materials; and private and public research agencies have information that is valuable in the planning and operation of a dehydration plant. In fact, most prospective dehydrators would be unable to get past the initial planning stages if it were not for the invaluable assistance offered by these consulting, manufacturing, and research organizations.

What Utilities are Needed?

Large quantities of potable water are needed in a vegetable dehydration plant. The amounts used vary considerably from plant to plant. In one survey of dehydration plants, for example, water used for processing a ton of potatoes was found to vary from 2,000 to 8,000 gallons--a four-fold difference. It is probable that potatoes require as much water as any vegetable. Onions and leafy vegetables, cabbage for example, may take considerably less water.

Fuel must be supplied in quantities sufficient not only for the dehydration step but also for such preparatory phases as blanching and heat peeling. To the extent that steam is used as the source of heat in processing, the type of fuel used is determined largely on the basis of cost and availability. The same situation holds for other methods of indirect heating. If direct firing is used for drying purposes as it is in some cases, the requirements are more critical. Because the products of combustion are mixed with the air blown over or through the drying vegetables, care must be taken to see that the combustion products do not cause off-flavors, discoloration, or other damage to the product.

Natural gas is probably the preferred fuel for direct-firing. Oil is sometimes used, but must be carefully controlled to insure complete combustion so as to avoid production of soot. Some types of oil have an excessive sulfur content. Since sulfur gases tend to be absorbed by the product, only the use of a proper type or mixture of fuel oil makes possible the production of a dehydrated vegetable in which the sulfur content is within specification tolerance.

Indirect-fired driers operate much like a home furnace in which the products of combustion are exhausted after they have heated the air through metal partitions. The type of fuel used, therefore, imposes no problems in the operation of the drier. Indirect firing is less efficient than direct firing, however.

Total heat requirement for a dehydration plant, including blanching, might range between 5 million and 10 million B.T.U. (British thermal units) for each ton of raw material processed. Actual requirements in some situations may be outside this range, depending upon more or less favorable conditions.

At common heating values for the several fuels, the requirements might be as follows for each ton of raw vegetable processed: 5,000-10,000 cu.ft. of natural gas; 35-70 gallons of heavy fuel oil; 300-600 pounts of bituminous coal; or 400-800 pounds of lignite.

The design of the forced-air system of the dehydrator has much to do with the power demand. Conveyor driers, with through circulation, probably take a minimum of power. Two-stage tunnel driers, where high velocities are used in the first stage, probably require more power. Roughly, 200-300 kilowatts is estimated to be the demand of a 5-ton-an-hour plant.

Are There Any Problems in Connection With Waste Disposal?

A dehydration plant processing 100 tons of potatoes a day will have up to 30 tons or more of waste potato material (cull-outs, peelings, trimmings, leaching losses, etc.) to dispose of. The organic material contained in the wastes may be roughly equivalent to that contained in the sewage flow from a town of 40,000 people. This material will be in part dissolved or mixed into the water used in processing (e.g., peelings removed in lye peeler) and will be, in part, solid wastes such as trimmings. The latter material can be disposed of as garbage and does not enter into the liquid-waste problem. Solid wastes are used for livestock feed, if suitable. They can be returned to the soil as fertilizer and conditioner, or they can be dumped if a satisfactory location is available.

Liquid or water-borne wastes are difficult to dispose of not only because of their volume but also because of the large quantities of soluble and suspended organic matter which they transport. Assuming that two gallons of water are used for each pound of potatoes processed, the liquid flow from a plant processing 100 tons of potatoes a day would be 400,000 gallons of water. This amounts to water one and one-quarter feet deep on an acre of land!

How can a plant dispose of this much liquid containing organic material? Inability to find a satisfactory answer to that question has forced many processing plants to shut down. There are several methods of disposal in use, and the location of the plant will generally determine which method can be used.

Liquid wastes can be discharged into streams. Unless the flow of water in the stream is sufficiently large, however, this method of disposal creates serious problems. The organic matter contained in the liquid wastes combines chemically with oxygen in the water. If the stream flow is small, the dissolved oxygen resources of that body of water will be quickly depleted. In most states anti-pollution laws forbid the dumping of sewage into streams or lakes, and some other means of disposal must be used.

In some locations processing plants dump their liquid wastes into existing sewers. If an existing system is large enough to handle such wastes, there is no problem. Waste treatment plants in most municipal sewage systems are designed to handle only a limited loading of organic matter, and if this amount is exceeded, the entire operating balance of the plant will be upset and objectionable conditions will exist. If such a situation exists, the municipality will likely prohibit the use of sewers for processing wastes. The municipality may be willing to enlarge its sewage handling and treating facilities, however, provided the processing plants pay additional costs incurred.

If the dehydration plant is located in sandy terrain, if there is sufficient area available, and if the location is far enough removed from urban areas, waste water can be drained into the soil. It may be necessary to remove all suspended solids prior to final disposal of wastes. Treatment of the liquid effluent with lime or iron sulfate is desirable to facilitate precipitation of finely suspended materials.

In some instances, liquid waste material can be run directly into shallow lagoons or closed areas of land diked on the edge from which the liquids drain into the soil. If none of these disposal methods can be used, the plant must have its own treatment system to remove or oxidize solids in the effluent. The water can then be discharged into streams or sewers.

By-product utilization of the waste material is often considered--for example, recovery of starch or alcohol from potato wastes. To be economically feasible, these recovery processes must be carried out on a very large scale. Even under most favorable conditions only the largest of dehydration plants could possibly consider by-product recovery.

Existing starch or alcohol plants might be able to use waste material from a dehydration plant. The low unit value of the waste material delivered to the recovery plant would necessitate a minimum of hauling costs. Location of the dehydration plant adjacent to the recovery plant, therefore, is essential.

The existence of a processing plant in a given location is not evidence that there is no waste-disposal problem. That plant itself may be looking for a new means of disposing of its wastes because of the passage or recent enforcement of anti-pollution legislation, or may already be taxing the capacity of existing facilities.

The prospective operator must investigate thoroughly the matter of waste disposal. Municipal, State, and federal laws applying to a location under consideration must be carefully studied. A satisfactory solution to the waste-disposal problem must be assured before a plant is built or purchased.

New Facilities or Old?

Inasmuch as the opportunity to use plant and equipment already available offers some chance for a saving in initial capital investment, any such facilities considered must be thoroughly investigated to see if they will do the job that is required of them in producing a quality product at low cost.

Among the items that might be considered are existing buildings and plant sites. Probably the first consideration is the location. Remembering the principles of plant location discussed earlier, one should appraise the available facilities concerned to see if the location is favorable. If not, and if additional operating costs would be incurred, the initial savings possible must be sufficient to offset the higher operating costs. The facility must also be appraised in light of available supply of labor, adequacy and quality of raw material that could be procured, and availability of necessary utilities. Satisfactory means must be available for disposing of waste material, both liquid and solid.

An existing building presents several problems in any adaptation to a use for which the building was not originally intended. The available space and its arrangement may not permit a layout that will insure most efficient operation. Storage space may be inadequate in both quality and size. A vegetable dehydration plant must operate in the strictest sanitary manner. It must be insect- and rodent-proof. It must be easily cleaned and kept clean. It must permit the handling of the product in the desired way so that it does not become contaminated. If an existing building cannot meet these requirements, then it must be discarded, or remodeled at additional cost.

Used equipment is often available. This also must pass the same scrutiny of sanitary requirements, particularly with respect to ease of cleaning. The equipment must have needed capacity and do the task required in an efficient manner. Each piece of equipment must be judged on its own merits and in consideration of new equipment that is available or can be built as specified.

Existing fruit dehydrators have been used to dehydrate vegetables, many of them successfully. Some of the raisin and prune dehydrators in California and several of the apple dehydrators in Washington are examples of successful adaptations. In addition to the problems of efficient operation and sanitation, the matter of heat and air velocities must be considered.

Dehydration is usually accomplished by the passage of heated air over or through the product. Velocities of less than about 600 lineal feet a minute, while satisfactory for most fruits, are considered inadequate for most vegetables in a tray type of drier. If an existing dehydrator cannot provide adequate air flow, it is obviously unsatisfactory. Furthermore, the air flow must be uniformly distributed to permit even drying. Required velocities are considerably less for through-flow of air, as in conveyor driers, but the same proportional differences exist between

the requirements for fruits and vegetables. Kiln types of fruit driers have seldom, if ever, been used satisfactorily for vegetables.

Heat requirements are also greater for most vegetables. The relatively higher moisture content of the vegetable, plus the more rapid evaporation of water that is possible, account for this greater demand. It is quite probable that most existing fruit dehydration plants could not meet the requirements for vegetable drying without extensive alterations.

There are certain instances where a dehydration process can be set up as an adjunct to an existing processing plant. Savings occur from the joint use of such facilities as receiving and shipping areas and equipment; boiler, utility, and supply facilities; and offices, rest rooms, and laboratories. Processing advantages are possible from the ready availability of experienced supervisors, technical employees, and skilled laborers, and from the benefits of established contacts in raw material procurement, marketing outlets, and other outside interests. The opportunity of grading and sorting raw material so that each process may run that quality which is best suited to its needs is certainly worthy of consideration.

The setting up of a vegetable dehydration plant as an adjunct to an existing operation may present some shortcomings, and must, therefore, be carefully considered and necessary precautions taken. Existing facilities, such as boilers, waste disposal systems, etc., may become overloaded with the added operation. The plant operator may look upon the dehydration line as a place to use the undesirable grades of raw material or to assign the less desirable labor, equipment, etc.

Under emergency conditions, certain governmental restrictions are imposed on new construction. The need for a new vegetable dehydration plant in a given area will be judged on the basis of suitability of location as it relates to raw material, transportation requirements, labor supply, and concentration of the defense industries and strategic distribution of facilities, and on the basis of critical materials and equipment needed. To minimize the use of critical metals, the new plant may have to utilize a much greater proportion of wood and masonry in construction than would normally be the case and may have to include a processing line lacking many labor-saving features.

To help the prospective dehydrator obtain information about equipment, a partial list of manufacturers is given in Appendix C. Inclusion of any name on this list does not imply a recommendation, nor is the absence of a name a negative recommendation. The names of equipment manufacturers were taken from trade registers usually available in libraries, and from catalogs and trade journal advertising.

How Much Will it Cost to Get Into This Business?

No one answer can be given to the question of what it costs to get into the business of vegetable dehydration, because no single answer will apply to all situations. Construction costs, for example, vary considerably, depending upon many different factors.

First, let us consider the choice of a process and the degree to which it is mechanized. Even with a given process, there are many ways of accomplishing the various steps. The more automatic an operation becomes, as a rule, the more costly the equipment and installation become. To offset this higher cost, however, labor costs should be less. Each builder will have his own ideas of how the plant should be constructed and of the relative importance of each processing step and the equipment required for each.

Second, the location of the plant. Local building costs such as labor rates, prices for materials, etc.; site cost and preparation; type of building required as determined by process, weather conditions, and local ordinances; method of sewage disposal used; and need for drilling a well--all of these factors and more will affect plant costs and will produce variations in costs according to location.

Third, whether new or used building and equipment are available, or whether the dehydration plant can be set up as an adjunct to an existing processing plant. An estimate based entirely on new plant and equipment may apply to only a portion of new dehydration plants; many newcomers will use existing or used facilities and will make some items of equipment at a lesser cost than the price of equipment already fabricated.

Fourth, the scale of operation. The larger plants, having a capacity of 5 tons or more of raw material an hour, can take advantage of a greater degree of mechanization, more specialized labor skills, and somewhat more efficient equipment of larger size and lesser cost per unit of capacity.

These qualifications are pointed out to show the limitation of any general cost estimate. Only by completely designing and engineering a plant for a specific site can one make a reliable estimate of probable construction cost. Even then, unexpected items of cost may come up.

The important thing, in preliminary planning, is the assurance that a proposed venture will be adequately financed. Not only must survey, engineering, and construction costs be covered, but working capital must also be provided. There will be a greater need for working capital at the beginning of operations than will be needed later when operations become normal. The learning period may prove especially costly. Inexperience, mistakes in judgment, or mismanagement may dissipate working capital at an excessive rate. In the last war, many plants were forced to close or depended upon government help because the operators underestimated their financial requirements. Newcomers planning to dehydrate for the civilian market will likely experience high promotional costs unless they have already established suitable distribution outlets. Promotional campaigns are very costly and a large fund must be available from which to finance these expenditures.

Construction of a dehydration plant capable of handling 5 tons of raw potatoes or carrots an hour to produce dice or strips will probably involve an expenditure in most cases for new building and equipment of over $500,000. Depending upon the conditions experienced, the actual cost in a given situation may vary many thousands of dollars above or below this figure. A potato plant of the type mentioned with a capacity of 1 ton of raw potatoes an hour may cost from one-third to

one-half as much as the 5-ton plants. Some experts on cost estimating say that the cost of many types of process plants increases at a six-tenths factor as the capacity is doubled.

Working capital needs will depend largely on the regularity of payments for goods sold and the time-lag in receiving payments. Assuming that there will be an average of 60 days between the time costs are incurred and the time payment is received in full, and a selling price of 40 cents a pound, cash and credit needs, plus possible advances on contracts, can be estimated as follows for a plant handling 5 tons of raw potatoes an hour:

Raw potatoes needed to make one pound dehydrated-----	7 pounds
Dehydrated potatoes produced per hour----------------	1,250 "
Dehydrated potatoes produced per 20 working-hour day---	25,000 "
Value of output per day, at 40 cents a pound--------------	$10,000
Value of output over a 60-day period---------------------	$600,000

Not all of this $600,000 will be for out-of-pocket costs, as the price received covers profits and amortization of capital investment. A reserve fund should be built up, however, as it is unwise to attempt operation on a margin that covers only ordinary out-of-pocket costs. Other expenditures will be involved too, such as advances to growers, prepaid expenses, and, as mentioned, promotional costs. Obviously, the operation of a 5-ton-an-hour dehydration plant is big business and requires a great deal of capital to function effectively.

Operating costs vary tremendously from plant to plant, depending upon innumerable combinations of factors. To assist the prospective dehydrator in properly evaluating the important items of cost and in avoiding undue emphasis on relatively minor items, the major cost components will be briefly discussed below.

Raw material costs usually amount to 40 to 60 percent of cost of production. For each $10 a ton paid for raw material, the cost of raw material needed to produce one pound of dehydrated product varies from 10 cents (at a 20-to-1 overall shrinkage ratio, as in cabbage) down to 3 cents (at a 6-to-1 ratio, as in sweetpotatoes).

Labor is usually the next most important item of cost. Labor costs vary from plant to plant, depending upon labor rates, degree to which plant is mechanized, and the relative efficiency with which labor us used. Since most of the labor is on the "wet-end" of the process--that is, in operations before dehydration, the raw-material-to-finished-product ratio (overall-shrinkage ratio) will have an important effect on unit labor costs; the higher the ratio for a given vegetable, the higher the labor cost per pound of finished product.

Next in order of importance are packaging material costs. Dehydrated vegetables sliced, diced, or stripped are quite bulky. For example, about 12 to 15 pounds of onion flakes can be put into a 5-gallon can. A No. 10 can will hold only 2 to 2-1/2 pounds. The cost of the can (at 10 cents each) would be 4 to 5 cents per pound of dried product. The fiberboard case used for No. 10 cans adds another 2 cents a pound to the packaging costs. Large drums would materially reduce packaging costs, particularly if the drums can be reused.

Indirect and overhead cost items include fuel and power, investment amortization, maintenance, supervision, office help, etc. The unit cost will depend not only upon operating conditions in a given plant but also on the methods of bookkeeping used and the degree to which the dehydration process is dependent on other plant operations. Length of operating season is an important factor influencing costs.

Fuel and power costs for drying depend mainly upon the amount of water evaporated from the product, but depend also on the fuel used and on the type of heating unit in the drier. The costs per pound of the various finished products will be largely proportional to the ratio of prepared material fed to the drier to material taken from drier.

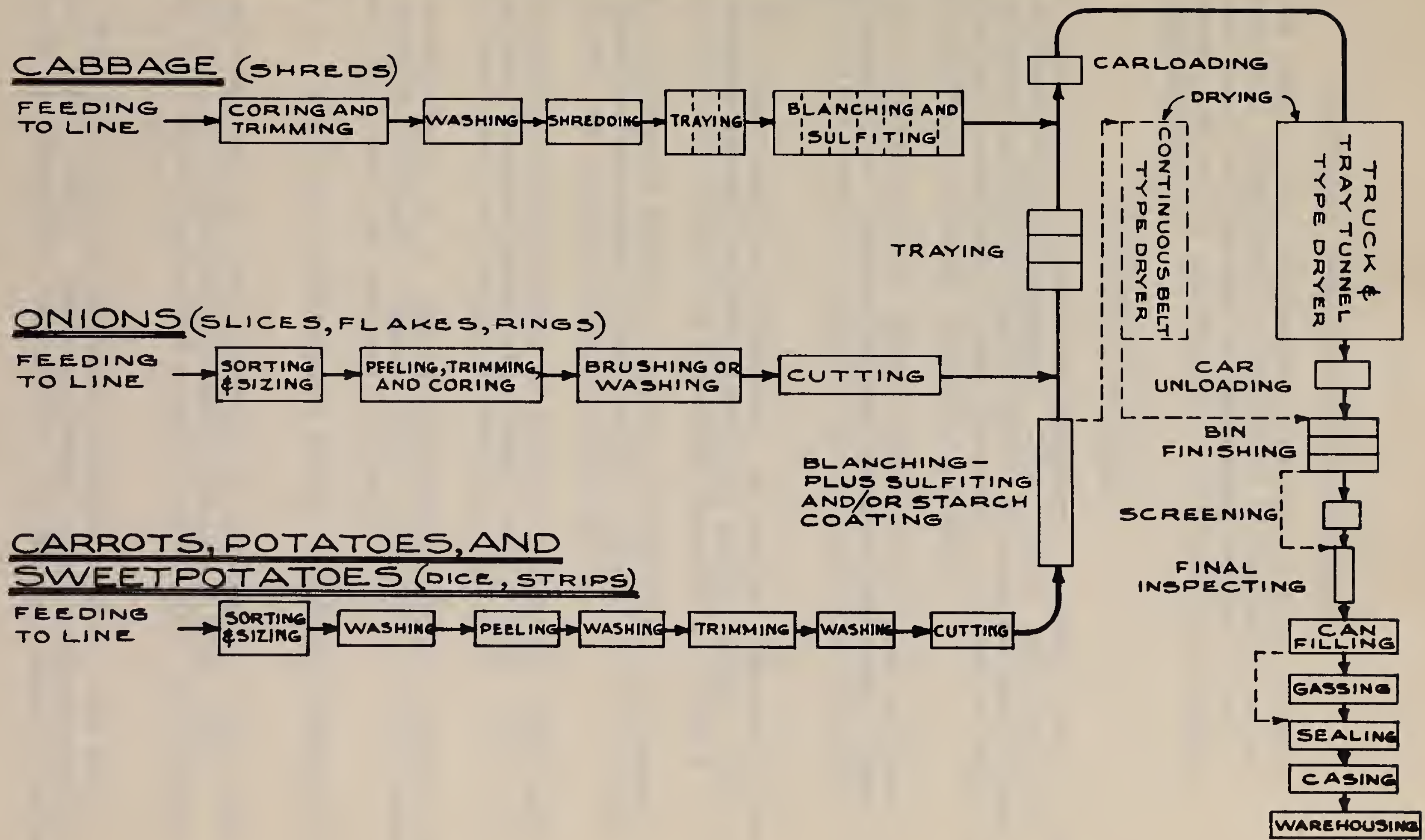
Selection of the scale of operation for a food processing plant is usually based largely upon economic factors. In a peacetime economy, low operating costs are essential to profitable operation. In an emergency period, factors other than economics must also be carefully considered in the choice of the scale of operation.

As long as the plant is of a size clearly beyond the uneconomical small sizes, it should be able to compete successfully so far as costs related to plant size are concerned. Other cost factors, such as raw material cost, are so much more important, relatively, that a plant, by careful and efficient operation, may more than offset any cost disadvantage it may have because of size.

Small plants, handling one ton or less raw material an hour, are not usually in a commercially competitive position unless they have some special advantage such as low-cost raw material, low labor cost, longer operating season, etc. Small plants, operating as community projects or on family farms, often justify themselves by making possible the saving of crops which have no ready market or as a community service. Their value in war time is limited by the fact that output per unit of operating labor and construction materials is low. The smallest plants may not be able to produce as consistent quality products as the larger plants.

APPENDIX A

TYPICAL MAJOR PROCESSING STEPS DEHYDRATION OF SELECTED VEGETABLES



Appendix B--List of Selected References

The items in this bibliography have been grouped by major subjects. Arrangement of references in each group is approximately in the order of their contribution to each phase of vegetable dehydration. Periodicals are arranged alphabetically.

Dehydration Technology

U. S. Bureau of Agricultural and Industrial Chemistry. Vegetable and Fruit Dehydration--A Manual for Plant Operators. 1944. 218 p. (U.S. Dept. of Agriculture Miscellaneous Publication 540.) Although now out of print, this publication is available in many libraries. It contains general and specific information on theory, practice, and costs.

Van Arsdel, W. B. Principles of the Drying Process with Special Reference to Vegetable Dehydration. Western Regional Research Laboratory, Albany, Calif. 1951. 89 p. (U.S. Bureau of Agricultural and Industrial Chemistry, AIC-300.)

Van Arsdel, W. B. Tunnel-and-Truck Dehydrators, as Used for Dehydrating Vegetables. Western Regional Research Laboratory, Albany, Calif. 1951. 30 p. (U. S. Bureau of Agricultural and Industrial Chemistry, AIC-308.)

Lindquist, F. E. Storing and Handling Vegetables for Dehydration. Western Regional Research Laboratory, Albany, Calif. 1951. 7 p. (U.S. Bureau of Agricultural and Industrial Chemistry, AIC-325.)

Olson, R. L. Sanitation and Microbiology as Related to Vegetable Dehydration. Western Regional Research Laboratory, Albany, Calif. 1952. 14 p. (U.S. Bureau of Agricultural and Industrial Chemistry, AIC-344.)

Olson, R. L., and Harrington, W. O. Dehydrated Mashed Potatoes--A Review. Western Regional Research Laboratory, Albany, Calif. 1951. 23 p. (U.S. Bureau of Agricultural and Industrial Chemistry, AIC-297.)

von Loesecke, H. W. Drying and Dehydration of Foods. New York, Reinhold, 1943. 302 p.

Cruess, W. V., and MacKinney, G. The Dehydration of Vegetables. (Calif. Agricultural Experiment Station Bulletin 680), Berkeley. 1943. 76 p. Theoretical discussions, industrial methods, and a 3-page bibliography of additional information.

Cruess, W. V. Commercial Fruit and Vegetable Products. 3rd ed. New York, McGraw-Hill. 1948. 906 p. Presents standard commercial methods of processing fruits and vegetables--dehydration, sun-drying, canning, pickling, etc.

Jacobs, M. B., ed. The Chemistry and Technology of Food and Food Products. 2nd ed. New York, Interscience. 1951. 2580 p. in 3 vol. Both theory and practice are covered. Includes chapters on: The dehydration of foods, by E. Mrak and G. MacKinney; Unit operations and processes, by K. N. Garver; and Industrial waters, by F. C. Nachod and E. Nordell.

Ede, A. J., and Hales, K. C. The Physics of Drying in Heated Air with Particular Reference to Fruit and Vegetables. London. 1948. 50 p. (Great Britain Dept. of Scientific and Industrial Research, Food Investigation special report 53.)

Morris, T. N. The Dehydration of Food, with Special Reference to Wartime Developments in the United Kingdom. London. Chapman & Hall. 1947. 174 p.

Great Britain. Ministry of Food. Vegetable Dehydration in the United Kingdom. London. 1946. 177 p. (A publication in the Ministry's Scientific and Technical Series.) A detail review of British dehydration experience during World War II.

Burton, L. V. Dehydrator Uses New Technics. Food Indus. 15(11):59-63, 142-44, Nov. 1943. Description is given of the Caldwell, Idaho, plant producing dehydrated potatoes and onions.

Brown, J. G. How to Select Equipment for Food Processing Plants. Food Indus. 20(7):104-106, 204-206; (8):75-77, 199-200, July 1948.

Havighorst, C. R. One Percent Moisture Attained by Vacuum Dehydration. Food Indus. 16(4):67-71, April 1944. A method for dehydrating apples to low moisture levels is reported.

Woodroof, J. G., and others. Peeling with Lye. Food Indus. 20(6):101-108, June 1948. A summary is presented of the various procedures of using lye in peeling.

Anon. Steam Peelers for Potatoes. West. Canner and Packer 37(3):59, 61, March 1945.

Mazzola, L. C. Potato Peeling Methods Analyzed and Appraised. Food Indus. 18(11): 100-101, 224-28; (12):106-108, 212-14, Nov.-Dec. 1946.

Balls, A. K. What a Foreman Should Know About Enzyme Action. Food Indus. 20(2): 71, 222-28, Feb. 1948. An explanation in lay terms of significant enzymatic changes that are likely to occur in the processing of natural foodstuffs.

U. S. Bureau of Human Nutrition and Home Economics. Cooking Dehydrated Vegetables. Washington, D. C. 1944. 20 p. (U.S. Dept. of Agriculture, AIS-8.) Convenient recipes are given in this publication prepared for the civilian consumer.

Olson, R. L., and others. Recent Advances in Potato Granule Technology. Food Technol. 7(4):177-181, April 1953.

Masure, M. P., and others. Value of Starch Coating in the Preservation of Quality of Dehydrated Carrots. Food Technol. 4(3):94-97, March 1950.

Raw Material for Dehydration

Spangler, R. L. Standardization and Inspection of Fresh Fruits and Vegetables. Washington, D. C. 1946. 28 p. (U.S. Dept. of Agriculture, Miscellaneous Publication 604.) The details of Federal and State services for grading raw material are given.

Culpepper, C. W., Caldwell, J. S., and others. "Comparative Studies of Varieties of Certain Vegetables for Dehydration" and "Further Studies"... American Society of Horticultural Science Proc. 43:210-218, 1943 and 46:375-87, 1945. A summary of tests on variety suitability for different vegetables.

Wheeler, H. E. The Raw Material Problem in Vegetable Dehydration. Food Indus. 15(10):82, 110, Oct. 1943.

Ross, A. F., and others. Selecting and Storing Potatoes to Avoid Darkening. Food Indus. 18(7):77-79, 210-18, July 1946. Potatoes having less than 3 percent "reducing" sugars are recommended for dehydration, chips, or French-fries.

Dawson, J. C. Proper Raw-Material Inspections. Food Engin. 23(5):91-93, 168-70, May 1951. Specific procedures are described to insure adequate inspection and grading.

Pentzer, W. T., and Fisher, D. F. Handling and Storing Fresh Vegetables and Fruits for Dehydration. Beltsville, Md. 1944. 11 p. (U.S. Bureau of Plant Industry, Soils, and Agricultural Engineering.)

Stephenson, R. M. Aspects of Modern Onion and Garlic Dehydration. Food Technol. 3:364-66, Nov. 1949. The importance of suitable raw material is emphasized.

Thompson, D. What It Takes to Reap Good Grower Relations. Food Indus. 21(6): 37-39, June 1949. Importance and means of promoting good will between growers and processors.

Knott, J. E. Vegetable Growing. 4th ed. Philadelphia, Lea & Febiger. c1949. 314 p. Books like this and the two following cover general cultural and handling practices for commercial crops.

Shoemaker, J. S. Vegetable Growing. 2nd ed. New York, Wiley. 1953. 515 p.

Thompson, H. C. Vegetable Crops. 4th ed. New York, McGraw-Hill. 1949. 611 p.

American Society of Agronomy. Hunger Signs in Crops--A Symposium. 2nd ed. Washington, D.C. The Society and the National Fertilizer Assoc. c1949. 390 p. Imperfect plant nutrition is shown to diminish yield and damage product quality.

Plant Location

Burton, L. V. Where to Locate That Dehydration Plant. Food Indus. 15(2):72-73, 125, Feb. 1943.

Faith, W. L. Plant Location in Agricultural Process Industries. Chem. Engin. Progress 45(5):304-313, May 1949.

Aries, R. S. Plant Location. Section 26, p. 1719-1730, of Chemical Engineers' Handbook, edited by J. H. Perry. 3rd ed. New York. McGraw-Hill. 1950.

Design and Construction of Process Plants (A Chem. and Met. Report), Chem. and Metallurgical Engin. 48(5):75-122, May 1941.

Wood, H. A. Industrial Plant Location. Canadian Chem. and Process Indus. 33:609-12, July 1949.

Plant Management and Employee Supervision

Nadler, G. Industrial Engineering Cuts Labor, Time, Handling. Food Indus. 21(5): 75-77, May 1949. Analysis of operations often suggests savings.

Lawler, F. K. Automatic Control of the Dehydration Processes. Food Indus. 15(12): 89-96, Dec. 1943.

Heller, G. E. Control Instrument Application to Dehydraters. Canning Age 24: 294-295, 356-357, 374, May-June 1943. Specific installations are discussed.

Spriegel, W. R., and Lansburg, R. H. Industrial Management. 4th ed. New York, Wiley. 1947. 656 p.

U. S. Bureau of Agri. and Industrial Chemistry, Western Regional Research Laboratory, Albany, Calif. AIC-39, Information Sheet on Cost Accounting for Vegetable Dehydration Plants. 1944. 8 p.

Bergen, M. J. Elements of Supervision and Tools of Supervision. A chapter, p. 26-47, in Plant Engineering Handbook, ed. by W. Staniar. New York, McGraw-Hill. 1950.

Spriegel, W. R., and Schulz, E. Elements of Supervision, New York. Wiley. c1942. 273 p.

Turner, W. D. Water for Municipal and Industrial Use. Chapter 6 of 6th ed., p. 194-235 of Vol. 1 of Rogers Industrial Chemistry, ed. by C. C. Furness. New York. Van Nostrand. 1942.

Curtis, H. A., and others. Fuels. Section 22 of 3rd ed, p. 1559-1596 of Chemical Engineers' Handbook, ed. by J. H. Perry. New York, McGraw-Hill. 1950. Includes data on average B.T.U. content of the several types of fuels.

Pinder, K. Industrial-Plant Power Distribution and Lighting. Section 13, p. 849-959 of Plant Engineering Handbook, ed. by W. Staniar. New York, McGraw-Hill. 1950.

Plant Sanitation and Pure Food Requirements

Association of Food Industry Sanitarians, Inc. Sanitation for the Food-Preservation Industries. New York. McGraw-Hill. 1952. 284 p.

Griffin, C. W., Jr. Selling Management on Plant Sanitation. Food Engin. 23(6): 76-79, June 1951.

Parker, M. E. Food Plant Sanitation. New York, McGraw-Hill. 1948. 447 p. Includes information on equipment design, cleaning and sanitizing materials, water supply, waste disposal, and operating techniques.

Linsley, F. G., and Michelbacher, A. E. Insects Affecting Stored Food Products. Berkeley. 1943. 44 p. (Calif. Agr. Expt. Sta. Bul. 676.) Identification, life history, probable damage are included.

Herrick, A. D. Food Regulations and Compliance.New York. Revere Pub. Co. c1944 (v.1). 1947 (v.2) 1288 p. Covers both Federal and State requirements and enforcement.

Kleinfeld, V. A., and Dunn, C. W. Federal Food, Drug, and Cosmetic Act: Judicial and Administrative Record 1938-1949. New York. Commerce Clearing House. 1949. 895 p. This fully documented volume covers descriptions of actual cases with administrative opinions and judicial decisions.

Waste Disposal

Eldridge, E. F. Industrial Waste Treatment Practice. New York. McGraw-Hill. 1942. 401 p. Includes a chapter on canning-factory wastes.

Warrick, E. F., and others. Methods of Treating Cannery Wastes. Washington, D.C. 1939. 91 p. National Canners Association Bul.. 28-L.

Gray, H., and Ludwig, H. F. Characteristics and Treatment of Potato Dehydration Wastes. Sewage Works Jour. 15(1):71-77, Jan. 1943.

Pollution Control. A Chemical Engineering Report. Chem. Engin. 58(5):111-158, May, 1951.

Anable, A., and Kite, R. P. Pollution Abatement--Appraisal of Current Regulations. Chem. Engin. Progress 44(1):3-16, Jan. 1948.

Imhoff, K., and Fair, G. M. Sewage Treatment, New York. Wiley. 1940. 370 p.

Vasak, O. R., and Shaw, W. L. A Selected Bibliography of Periodical Literature on Fruit and Vegetable Wastes. Western Regional Research Laboratory, Albany, Calif. 1949. 12 p. (U.S. Bureau of Agri. and Industrial Chemistry, AIC-232.)

Packaging

U. S. Agricultural Research Administration. Experimental Compression of Dehydrated Foods. Washington, D.C. 1948. 57 p. (U.S. Dept. of Agriculture Miscellaneous Publication 647.) Reports of experimental research carried on by three Bureaus of the ARA and one Branch of the PMA, on seven vegetables, five fruits, egg powder, and several other products.

Continental Can Co., Research Staff. New Facts About Packaging and Storing Dehydrated Foods. Food Indus. 16(3):63-67; (4):76-78, 135; (5):86-90, 137-139; (6):89-92, 135; (7):86-89; (8):90-92, 135-136; (9):76-78, 122: (10):90-92, 140; (11):89-91, 141; (12):94-96, 149; 17(1):96-98, 160; (2):91-93, March 1944-Feb. 1945.

Grundy, A. V. Packaging for Combat Conditions. Food Indus. 22(5):77-79, 216, May 1950. Military packaging requirements are listed and explained.

Periodicals

The prospective operator should review the many periodicals in the food processing field. During the years 1941 through 1945, many articles were published on dehydration. Much of the information in those articles will still be of value in the planning of a dehydration plant.

AGRICULTURAL INDEX. Published monthly by the H. W. Wilson Co., New York. An index of significant publications on agricultural subjects including the processing of agricultural commodities.

FOOD ENGINEERING. Published monthly by McGraw-Hill Pub. Co., New York. Formerly issued under the title "Food Industries" until April 1951. Follows the trend in food processing toward better-engineered processes, equipment, products, and packages.

FOOD INDUSTRIES, with Vol. 23, No. 4 became FOOD ENGINEERING (see above).

FOOD PACKER. Published monthly by Vance Pub. Corp., Chicago. Formerly known as "Canning Age." This trade publication contains articles on dehydration as well as food processing in general.

FOOD PROCESSING. Published monthly by Putnam Pub. Co., Chicago. Primarily to emphasize latest developments in equipment for food plants.

FOOD RESEARCH. Published six times a year by Institute of Food Technologists, Chicago. Primarily concerned with technology of food processing and utilization.

FOOD TECHNOLOGY. Published monthly by Institute of Food Technologists, Chicago. Scientific contributions concerning food preparation and utilization.

INDUSTRIAL ARTS INDEX. Published monthly by H. W. Wilson Co., New York. Trade items and management articles indexed by subject.

MODERN PACKAGING. Published monthly by Modern Packaging Corp., New York. Development, trends, performance characteristics of packaging and materials.

WESTERN CANNER AND PACKER (monthly) and its annual Statistical Review and Yearbook number. Published by Miller Freeman Publications, San Francisco. Extensive statistical tables and reviews of current processing season appear in the annual.

Appendix C--Partial List of Companies Manufacturing Equipment Used in Vegetable Dehydration Plants

(The manufacturers listed are not recommended over other manufacturers of similar equipment.)

	Type of equipment					
	Air conditioning	Dehydrating	Packaging	Preparation	Control instruments	Water supply & waste handling
Allis-Chalmers, Inc., Milwaukee, Wis.	X	X	-	X	X	-
American Can Co., New York, N.Y.	-	-	X	-	-	-
Benner-Nauman, Inc., Oakland, Calif.	-	-	-	X	-	-
Berlin Chapman Co., Berlin, Wis.	-	X	-	X		-
Boutell Mfg. Co., Rochester, N.Y.	-	-	-	X	-	-
Chisholm-Ryder Co., Inc., Niagara Falls, N.Y.	-	-	X	X	-	-
Cleaver-Brooks Co., Milwaukee, Wis.	-	X	-	-	-	-
Continental Can Co., New York, N.Y.	-	-	X	-	-	-
Exact Weight Scale Co., Columbus, Ohio	-	-	X	-	-	-
Fibreboard Products Co., San Francisco, Calif.	-	-	X	-	-	-
Food Machinery & Chemical Corp., San Jose, Calif.	-	-	X	X	X	X
Hamachek, Frank, Machine Co., Kewaunee, Wis.	-	-	-	X	-	-
Horix Mfg. Co., Pittsburgh, Pa.	-	-	X	X	-	-
Jeffrey Mfg. Co., Columbus, Ohio	-	-	-	X	-	X
Knipschild Dehydrator Co., St. Helena, Calif.	-	X	-	-	-	-
Langsenkamp, F. H., Co., Indianapolis, Ind.	-	-	-	X	-	-
Link-Belt Co., Chicago, Ill.	-	-	-	X	-	X
Minneapolis-Honeywell Regulator Co., Philadelphia, Pa.	-	-	-	X	X	-
Pittsburgh Lectrodryer Corp., Pittsburgh, Pa.	X	-	-	-	-	-
Proctor & Schwarz, Inc., Philadelphia, Pa.	-	X	-	-	-	-
Robins, A.K., & Co., Inc., Baltimore, Md.	-	-	-	X	-	-
Scott Viner Co., Columbus, Ohio				X	-	-
Sturtevant Div., Westinghouse Electric Co., Boston, Mass.	X	X	-	-	-	-
Sprout, Waldron & Co., Inc., Muncy, Pa.	-	-	-	X	-	-
Taylor Instrument Co., Rochester, N.Y.	-	-	-	-	X	-
Urschel Laboratories, Inc., Valparaiso, Ind.	-	-	-	X	-	-
Wallace & Tiernan Co., Inc., Belleville, N.J.	-	-	-	-	-	X